Flow Visualization
MCEN 4151

Spring 2013

Team Project I

Jeremy Parsons

University of Colorado at Boulder

Introduction:

The image shown is a one of the images captured by Team 3 during our ferrofluid experimentation. The original photograph credit must be shared with Daniel Ming, Anna Gilgur and Jonathan Fritts. Each group member participated in the experimentation process aided in the capture of the collective photograph collection. Ferrofluid has special characteristics and unique behaviors when exposed to magnetic field. Ferrofluids were originally discovered in the 1960's by NASA in an effort to come up with a method of controlling liquids in space. The benefits of ferrofluids became obvious, the fluid could be controlled with a magnetic field and varying the strength of the field could force the fluid to flow in a desired direction [1]. The purpose of this image in particular is to show the spiked "normal instabilities" that occur on the surface of the ferrofluid when magnetized. The physics behind why these unique formations occur are covered in the next section.

Ferrofluid Physics:

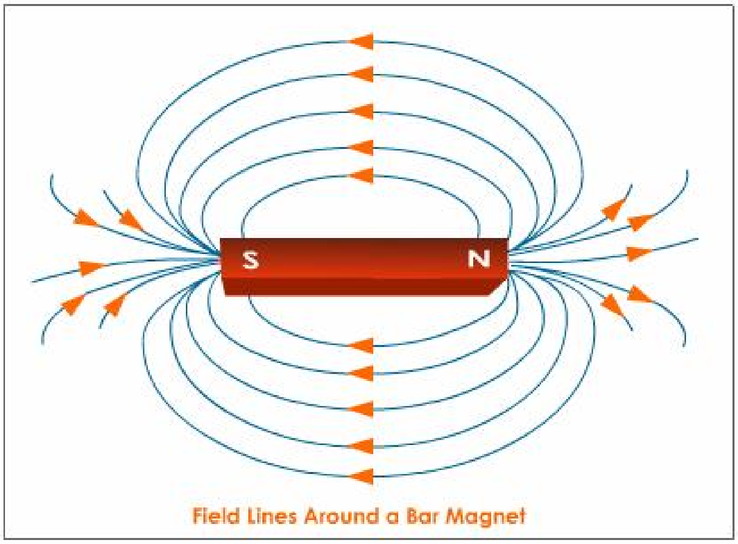
The phenomena shown, and most commonly affiliated with ferrofluid is the spiked "Normal Field Instability". Most ferrofluids contain small particle, magnetite ($Fe3O4$) and this reacts to magnetism. As the fluid is exposed to a magnetic field, an array of hexagonal peaks begin to form, upon increasing the magnitude of the magnetic field this array becomes square as it crosses into its second threshold [2]. The spikes form along the field lines of the magnet in use, the stronger the field the more drastic the formations that occur. The spikes are the result of favored energy states. The magnetic field can travel in the fluid more easily than air so it pushes the fluid outward, while the fluid's surface tension pulls in back in, resulting in the spiky formations shown. The sizes of the spikes are also controlled by the overall surface tension of the liquid, the higher the surface tension the more the fluid will want to retain its original shape.

Image:

This image was taken on March 2, 2013 in the ITLL Laboratory. We utilized a lab station to take the pictures while using many precautions. The ferrofluid has an incredible tendency to stain anything it touches so we had to spread paper on every working surface and wear gloves and old clothing. The majority of our images were taken using the setup seen in the unedited image below. Using the glass fishbowl allowed us to position the magnets feely beneath the plate to yield different configurations in the ferrofluid. We initially had some small magnets that were provided with the ferrofluid due to their strength but it turned out that the simple refrigerator bar magnet produced the best results. Multiple bolt/washer/nut combinations were used in the experimentation phase until about five configurations yielded the most appealing results. The image shown is simply two small bolts placed above opposite ends of the bar magnet with both of the heads facing upward. I elected to use this image because the ferrofluid groups toward the

North/South poles of the magnet, and avoids the middle where the magnetic field is less powerful, see Figure 1 [3]. The bolts used are magnetized by the magnet beneath and act as pseudo-poles for the magnetic field. This is what leads to the grouping that occurs on opposite sides of the bolts in the image.

Photographic Technique:



The following is the settings used to capture the image.

- Camera: Cannon Rebel XT Digital
- Lens: Cannon 80mm Macroscopic Lens
- Image size: Original – 3456x2304 pixels and Edited – 866x678 pixels
- Exposure Settings: Macro mode with ISO-800, F/-4.5
- Exposure Time – 1/60 second
- Editing- Cropping, color balance and color contrast adjustments were done in Photoshop CS6

Original Image

Edited Image

The original and edited images are shown above. The edited image was cropped in all four directions to isolate the ferrofluid interaction. A manipulation of color balance removed some of the yellows from the light source and brought out some of the deep purples and blues and the curves tool was used to sharpen the contrast between the foreground and the background significantly. The clone stamp tool was used to remove distracting shadows in the background and the spot healing brush was used to clean the edges were the there was blurring.

Commentary:

I enjoy this image very much because it really demonstrates the unique characteristics and behavior of ferrofluid. It is a relatively newly discovered substance and has very unique properties that are both scientifically intriguing as well as aesthetically pleasing. This experiment allowed our team to capture some very interesting images while learning about the unique substance. My personal interest in ferrofluid has been further increased and this excites me to work with such a unique material in the future.

Citations:

1) "Ferrofluids." Exploring the Nanoworld (2008): n. pag. National Science Foundation. Web. 5 Mar.

2013. <http://education.mrsec.wisc.edu/background/ferrofluid/index.html>.

2) A Materials Science Companion by A. B. Ellis, M. J. Geselbracht, B. J. Johnson, G. C. Lisensky, and

W. R. Robinson. Copyright © 1993, American Chemical Society, Washington, DC.

3) " Mapping of Magnetic Lines of Force." . N.p.. Web. 13 Mar 2013. <http://www.tutorvista.com/content/science/science-ii/magnetic-effects-electric-current/mapping-magnetic-lines.php>.